



Enlarged Ship Concept Applied to RORO Cargo/Passenger Vessel

J.M.J. Journée (TUDelft)
Jakob Pinkster (TUDelft)
S.G. Tan (MARIN)

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Edited by M.W.C. Oosterveld and S.G. Tan*

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The Hague, The Netherlands, September 1998

edited by

M.C.W. Oosterveld

*MARIN - Maritime Research Institute Netherlands,
Wageningen, The Netherlands*

and

S.G. Tan

*MARIN - Maritime Research Institute Netherlands,
Wageningen, The Netherlands*



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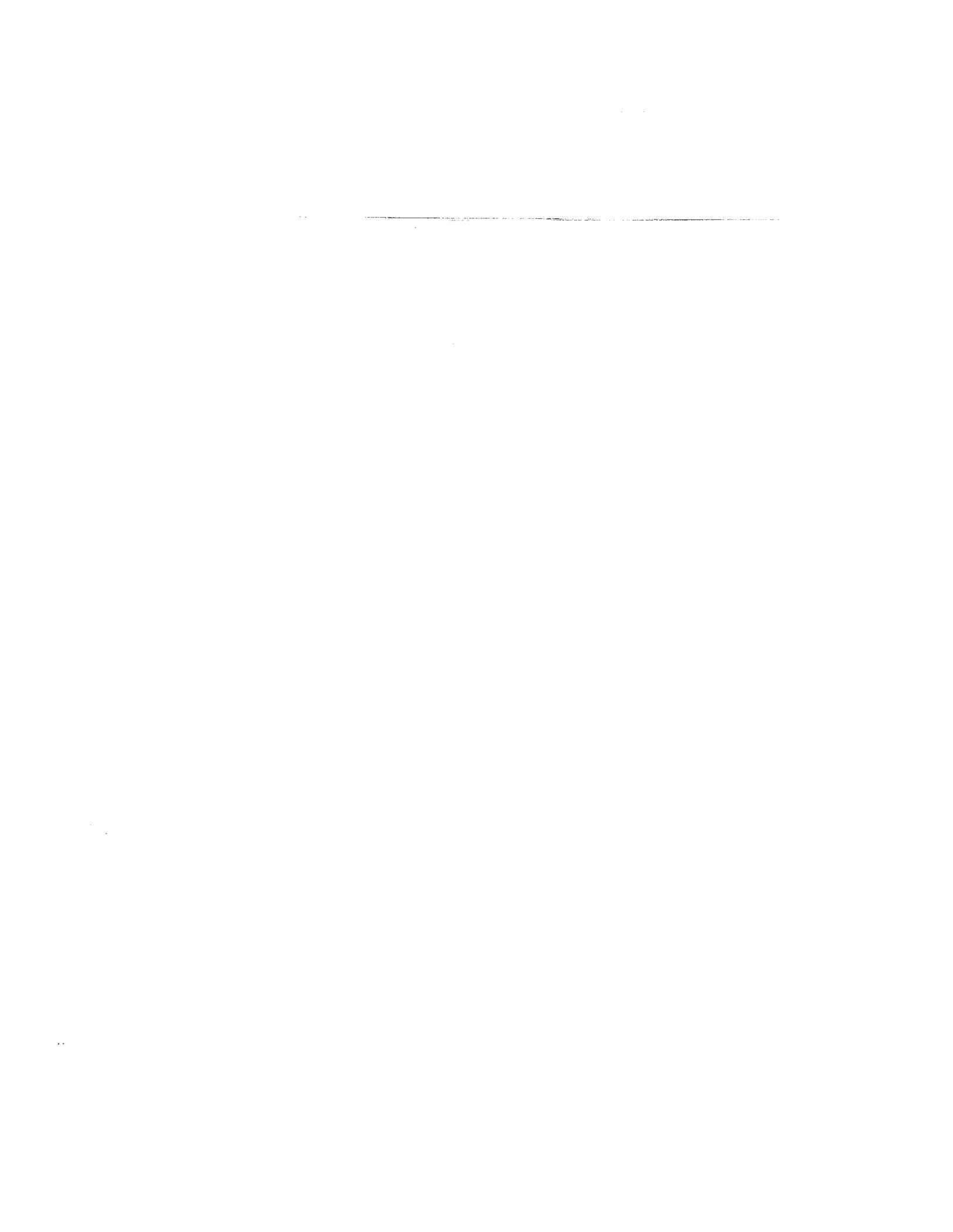
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These Proceedings consist of papers presented at the 7th International Symposium on Practical Design of Ships and Mobile Units. The Symposium was held at the Congress Centre in The Hague, The Netherlands, on 20-25 September 1998. The Symposium was organized by:

MARIN	Maritime Research Institute Netherlands
KIvI	Royal Institute of Engineers in The Netherlands
KM	Royal Netherlands Navy
NVTS	Netherlands Association of Maritime Engineers
TNO	Netherlands Organization for Applied Research
TU Delft	Delft University of Technology

These organizations are represented in the Local Organizing Committee.

The Local Organizing Committee organized the Symposium under supervision of the PRADS's Standing Committee. The Symposium benefited from the generous support of a number of Sponsors. These, together with the membership of the committees, are listed in the following.

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Maritime Research Institute Netherlands

P.O. Box 28, 6700 AA Wageningen, The Netherlands

telephone : +31 317 49 32 19

fax : +31 317 49 32 45

PREFACE

These Proceedings contain the papers presented at the 7th International Symposium on Practical Design of Ships and Mobil Units. The Symposium was held at the CONGRESS CENTRE in The Hague, The Netherlands, on 20 - 25 September 1998.

The overall aim of PRADS Conferences is to advance the design of ships and mobile marine structures through the exchange of knowledge and the promotion of discussions on relevant topics in the fields of naval architecture and marine and offshore engineering. Greater international co-operation of this kind can help improve design and production methods and so increase the efficiency, economy and safety of ships and mobile units. Previous symposia have been held in Tokyo ('77 and '83), Seoul ('83 and '95), Trondheim ('87), Varna ('89) and Newcastle ('92).

The main themes of this Symposium are Design Synthesis, Production, Ship Hydromechanics, Ship Structures and Materials and Offshore Engineering.

Proposals for over two hundred papers have been received for PRADS '98 from 25 countries, and 126 have been accepted for presentation at the Conference. Given the high quality of the proposed papers, it has been a difficult task for the Local Organising Committee to make a proper balanced selection.

Some topics which attracted many papers were Design Loads, Design for Ultimate Strength, Impact of Safety and Environment, Grounding and Collision, Resistance and Flow, Seakeeping, Fatigue Considerations and Propulsor and Propulsion Systems. The great current interest in these topics and the high quality of the papers guarantee a successful Conference.

The success of PRADS '98 depends on the great contributions of the participants with a special acknowledgement to the authors.

We as Local Organizing Committee have done our utmost to create the proper atmosphere for an interesting and enjoyable conference.

M.W.C. Oosterveld and S.G. Tan



CONTENTS

DESIGN SYNTHESIS

DESIGN - MARINE TRANSPORTATION SYSTEMS

- TRA-NESS “New Ship Concept in the Framework of Short Sea Shipping” 3
 A European Targeted Research Action: Results and Exploitation Aspects
C. Camisetti
- Principal Trends of Container Vessels Development 13
W. Chadzyński
- Hydrodynamic Impact on Efficiency of Inland Waterway Vessels 23
A.G. Lyakhovitsky

DESIGN - NOVEL SHIP CONCEPTS

- Small Waterplane Area Triple Hull (SWATrH) for Mega Yacht Purposes 29
Ulrich Heinemann
- The Design of a New Concept Sailing Yacht 37
J.J. Porsius, H. Boonstra and J.A. Keuning
- Enlarged Ship Concept Applied to RO-RO Cargo/Passenger Vessel 45
J.M.J. Journée, Jakob Pinkster and S.G. Tan

DESIGN - DESIGN LOADS

- Use of Non-Linear Sea-Loads Simulations in Design of Ships 53
L.J.M. Adegeest, A. Braathen and R.M. Løseth
- Numerical Study of the Impact of Water on Cylindrical Shells, Considering Fluid-Structure Interactions 59
M. Arai and T. Miyauchi
- Structural Response in Large Twin Hull Vessels Exposed to Severe Wet Deck Slamming 69
O.D. Økland, T. Moan and J.V. Aarsnes
- Structural Dynamic Loadings Due to Impact and Whipping 79
Kenneth Weems, Sheguang Zhang, Woei-Min Lin, James Bennett and Yung-Sup Shin
- Improved Ship Detail Finite Element Stress Analysis 87
Neil G. Pegg, David Heath and Mervyn E. Norwood
- Prediction of the Sectional Forces and Pressures on a Free-Fall Lifeboat During Water Entry 95
M. Reaz H. Khondoker

DESIGN - DESIGN FOR ULTIMATE STRENGTH

A Computational Method for Analysis of LNG Vessels with Spherical Tanks 103
F.Kamsvåg, E. Steen and S. Valsgård

The Influence of Adjoining Structures on the Ultimate Strength of Corrugated Bulkheads 111
Jeom Kee Paik, Anil K.Thayamballi and Sung Geun Kim

Ultimate Strength Formulation for Ship's Grillages under Combined Loadings 125
S.-R. Cho, B.-W. Choi and P.A. Frieze

DESIGN - GROUNDING AND COLLISION

Collision Resistance and Fatigue Strength of New Oiltanker with Advanced Double Hull Structure 133
J.W. Lee, H. Petershagen, J. Rörup, H.Y. Paik and J.H. Yoon

Failure Criteria for Ship Collision and Grounding 141
L. Zhu and A.G. Atkins

On Ductile Rupture Criteria for Structural Tear in the Case of Ship Collision and Grounding 149
E. Lehmann and X. Yu

Design of Corrugated Bulkhead of Bulk Carrier against Accidental Flooding Load 157
Hiromu Konishi, Tetsuya Yao, Toshiyuki Shigemi, Ou Kitamura and Masahiko Fujikubo

Analysis of the Collision between Rigid Bulb and Side Shell Panel 165
G. Woisin

A Study on the Improved Tanker Structure against Collision and Grounding Damage 173
O. Kitamura, T. Kuroiwa, Y. Kawamoto and E. Kaneko

Plastic Buckling of Rectangular Plates Subjected to Combined Loads 181
C.H. Shin, Y.B. Kim, J.Y. Lee and C.W. Yum

Investigations into the Collapse Behaviour of Inland Vessels 189
A. Meinken and H.-J. Schlüter

DESIGN - IMPACT OF SAFETY AND ENVIRONMENT

The Role of Shipboard Structural Monitoring Systems in the Design and Safe Operation of Ships 201
F.H. Ashcroft and D.J. Witmer

Rough Weather Ship Performance - A Quality to be Introduced into the Preliminary Design Process 209
J. Näreskog and O. Rutgersson

Steady Behaviour of a Large Full Ship at Sea 223
Shigeru Naito and Kenji Takagishi

Multiattribute Design Synthesis for Robust Ship Subdivision of Safe Ro-Ro Vessels <i>G. Trincas</i>	231
--	-----

On the Effect of Green Water on Deck on the Wave Bending Moment <i>Zhaohui Wang, Jørgen Juncher Jensen and Jinzhu Xia</i>	239
--	-----

Development of a Formal Safety Assessment System for Integration into the Lifeboat Design Process <i>P. Sen, R. Birmingham, C. Cain and R.M. Cripps</i>	247
--	-----

DESIGN - USE OF PROBABILISTIC METHODS

Reliability Based Quality and Cost Optimization of Unstiffened Plates in Ship Structures <i>Weicheng Cui, Alaa E. Mansour, Tarek Elsayed and Paul H. Wirsching</i>	255
---	-----

Hull Girder Safety and Reliability of Bulk Carriers <i>D. Béghin, G. Parmentier, T. Jastrzêbski, M. Taczala and Z. Sekulski</i>	261
--	-----

Review of Statistical Models for Ship Reliability Analysis <i>J. Parunov and I. Senjanović</i>	273
---	-----

DESIGN – METHODOLOGY

Automatic Hull Form Generation: A Practical Tool for Design and Research <i>R.W Birmingham and T.A.G.Smith</i>	281
---	-----

Hull Form Modelling Using NURBS Curves and Surfaces <i>M.Ventura and C.Guedes Soares</i>	289
---	-----

A New Transformation Method for the Designed Waterline <i>Jun Zhang, Hongcui Sheng and Mingdao Cheng</i>	297
---	-----

DESIGN – MISCELLANEOUS

Multiple Criteria Design Optimisation of RO-RO Passenger Ferries with Consideration of Recently Proposed Probabilistic Stability Standards <i>K.W. Hutchinson, P. Sen, I.L. Buxton and W. Hills</i>	303
--	-----

Is Tonnage Measurement Still Necessary? <i>Roman Albert</i>	313
--	-----

PRODUCTION

PRODUCTION - DESIGN FOR PRODUCTION

- Product Modelling for Design and Approval in Shipbuilding 323
U. Rabien and U. Langbecker
- Design for Production 331
George Bruce, Bill Hills and Richard Storch
- Ship Hull Surface Fairing System 341
T.K. Yoon, D.J. Kim, Y.W. Chung, S.Y. Oh, H.K. Leem and N.J. Park

PRODUCTION - PRODUCTION MANAGEMENT AND INFORMATION SYSTEMS

- An Evolutionary Approach to the Scheduling of Ship Design and Production Processes 351
J.A. Scott, D.S. Todd and P. Sen
- A Study on the Production-Oriented Structural Design Information System of Panel Blocks 359
Joo-Sung Lee and Gu-Gun Byun
- The Assessment of Ship Hull Weight Uncertainty 365
K. Žiha, I. Mavrić and S. Maksimović

SHIP HYDROMECHANICS

HYDROMECHANICS - RESISTANCE, COMPUTATIONAL FLUID DYNAMICS

The CALYPSO Project: Computational Fluid Dynamics in the Ship Design Process 373

J. Tuxen, M. Hoekstra, H. Nowacki, L. Larsson, F. van Walree and M. Terkelsen

Computing Free Surface Ship Flows with a Volume-of Fluid-Method 381

C. Schumann

Development of Computational System for Flow around a Ship and its Validation with Experiments 387

Wu-Joan Kim, Suak-Ho Van, Do-Hyun Kim and Geun-Tae Yim

HYDROMECHANICS - RESISTANCE, HULL FORM OPTIMISATION

A New Hull Form for a Venice Urban Transport Waterbus: Design, Experimental and Computational Optimisation 395

H.C. Raven, M. van Hees, S. Miranda and C. Pensa

A System for the Experimental Determination of the Hydrodynamic Impact of M/Bs Operating in Venice 405

F. Balsamo, A. Paciolla and F. Quaranta

An Inverse Geometry Design Problem in Optimizing the Hull Surfaces 411

Shean-Kwang Chou, Cheng-Hung Huang, Cheng-Chia Chiang and Po-Chuan Huang

Optimum Hull Form Design using Numerical Wave Pattern Analysis 421

Akihito Hirayama, Tatsuya Eguchi, Koyu Kimura, Akihiko Fujii and Moriyasu Ohta

Tankers: Conventional and Twin-Gondola Hull Forms 429

Eduardo Minguito, Henk H. Valkhof and Eric van der Maarel

Experimental and Computational Study on Resistance and Propulsion Characteristics for Ro-Ro Passenger Ship of Twin Propellers 439

Suak-Ho Van, Do-Hyun Kim, Bong-Ryong Son, Jung-Kwan Lee, Dong-Yul Cha and Jae-Kyoung Huh

Suak-Ho Van, Do-Hyun Kim, Bong-Ryong Son, Jung-Kwan Lee, Dong-Yul Cha and Jae-Kyoung Huh

HYDROMECHANICS - RESISTANCE, HIGH SPEED CATAMARANS

Geosim Experimental Results of High-speed Catamaran: Co-operative Investigation on Resistance Model Tests Methodology and on Ship-model Correlation 447

P. Cassella, C. Coppola, F. Lalli, C. Pensa, A. Scamardella and I. Zotti

P. Cassella, C. Coppola, F. Lalli, C. Pensa, A. Scamardella and I. Zotti

Influence of the Submergence and the Spacing of the Demihulls on the Behaviour of Multi-Hulls Marine Vehicles: A Numerical Application 453

Daniele Peri, Marco Roccaldo and Stefano I. Franchi

Daniele Peri, Marco Roccaldo and Stefano I. Franchi

Experimental Investigation on the Drag Characteristics of a High Speed Catamaran 461

R. Natarajan and Malle Madhu

HYDROMECHANICS - RESISTANCE, MISCELLANEOUS

A Study for Improvement in Resistance Characteristics of a Semi-Planing Ship
Yong-Jea Park, Seung-Hee Lee, Young-Gill Lee and Sung-Wan Hong 469

On Optimal Dimensions of Fast Vessel for Shallow Water
Milan Hofman 477

A Simple Surface Panel Method to Solve Unsteady Wing Problems
K. Nakatake, J. Ando and S. Maita 485

HYDROMECHANICS – SEAKEEPING, MOTIONS AND LOADS

Time-Domain Analysis of Large-Amplitude Responses of Ships in Waves
N. Fonseca and C. Guedes Soares 495

Wave-Induced Motions and Loads for a Tanker. Calculations and Model Tests
J. Lundgren, M.C. Cheung and B.L. Hutchison 503

Practical Time Domain Simulator of Wave Loads on a Ship in Multi-Directional Waves
Hisaaki Maeda and Chang Kyu Rheem 513

HYDROMECHANICS – SEAKEEPING, ADDED RESISTANCE AND SHIPPING WATER

Added Resistance of a Ship Moving in Small Sea States
Sverre Steen and Odd M. Faltinsen 521

BEAK-BOW to Reduce the Wave Added Resistance at Sea
Koichiro Matsumoto, Shigeru Naito, Ken Takagi, Kazuyoshi Hirota and Kenji Takagishi 527

A Prediction Method for the Shipping Water Height and its Load on Deck
Yoshitaka Ogawa, Harukuni Taguchi and Shigesuke Ishida 535

HYDROMECHANICS – SEAKEEPING, HULL FORM DEVELOPMENT

A Study on Motion Analysis of High Speed Displacement Hull Forms
Predrag Bojovic and Prasanta K. Sahoo 545

Hydrodynamic Development for a Frigate for the 21st Century
G.K. Kapsenberg and R. Brouwer 555

Theoretical Validation of the Hydrodynamics of High Speed Mono- and Multi-Hull Vessels Travelling in a Seaway
P.A. Bailey, D.A. Hudson, W.G. Price and P. Temarel 567

HYDROMECHANICS - SEAKEEPING, SLAMMING

Issues in the Assessment of Design Slamming Pressure on High Speed Monohull Vessels 577
Jianbo Hua

A Coupled Approach for the Evaluation of Slamming Loads on Ships 589
~~*A. Magee and E. Fontaine*~~

The Effect of Forward Speed on the Hydroelastic Behaviors of Ship Structures 597
S.-X. Du and Y.-S. Wu

HYDROMECHANICS - SEAKEEPING, MISCELLANEOUS

The Influence of Fixed Foils on Seakeeping Qualities of Fast Catamaran 605
W. Welnicki

Seakeeping Design of Fast Monohull Ferries 613
L. Grossi and S. Brizzolara

Prediction of Excessive Rolling of Cruise Vessels in Head and Following Waves 625
H.R. Luth and R.P. Dallinga

HYDROMECHANICS - MANOEUVRING

The Prediction of Ship's Manoeuvring Performance in Initial Design Stage 633
Ho-Young Lee and Sang-Sung Shin

An Experimental Study on the Effects of Loading Condition on the Maneuverability of Aframax-Type Tanker 641
In-Young Gong, Sun-Young Kim, Yeon-Gyu Kim and Jin-Whan Kim

Prediction of Crabbing in the Early Design Stage 649
F.H.H.A. Quadvlieg and S.L. Toxopeus

HYDROMECHANICS - PROPULSOR AND PROPULSION SYSTEMS, COMPUTATIONAL METHODS

Improvement in Resistance Performance of a Barge by Air Lubrication 655
Jinho Jang, Hyochul Kim and Seung-Hee Lee

Hydrodynamic Design of Integrated Propulsor/Stern Concepts by Reynolds-Averaged Navier-Stokes Techniques 663
Rich Korpus, Bryan Hubbard, Paul Jones, Chel Stromgren and James Bennett

Marine Propeller Hydroelasticity by means of the Finite/Boundary Element Method - A Preliminary Approach 671
Bogdan Ganea

HYDROMECHANICS - PROPULSOR AND PROPULSION SYSTEMS, STERN AND STRUTS

U.S.Navy Sealift Hydrodynamic Investigations 677
Siu C. Fung, Gabor Karafiath and Donald McCallum

The Influence of the Stern Frame Shape for a High Speed Container Ship on the Powering Performance 691
Kuk-Jin Kang, Ki-Sup Kim, Young-Jea Park, Chun-Ju Lee, In-Haeng Song and Il-Sung Moon

Some Aspects in Designing Shaft Brackets for High-Speed Vessels 699
A. Jonk and J.P. Hackett

HYDROMECHANICS - PROPULSOR AND PROPULSION SYSTEMS, WATERJETS

A Powering Method for Super High-Speed Planing Ships 709
Tadao Yamano, Takeshi Ueda, Isao Funeno, Tetsuro Ikebuchi and Yoshiho Ikeda

LINEAR-Jet: A Propulsion System for Fast Ships 717
M. Bohm and D. Jürgens

A Dynamic Model for the Performance Prediction of a Waterjet Propulsion System 727
Giovanni Benvenuto, Ugo Campora, Massimo Figari and Valerio Ruggiero

HYDROMECHANICS - PROPULSOR AND PROPULSION SYSTEMS, SEA TRIALS

Hydrodynamics in Pre-Contract Ship Design 735
Janusz T. Stasiak

Sea Trial Experience of the First Passenger Cruiser with Podded Propulsors 743
R. Kurimo

An Analysis of Full Scale Trial Results that takes Account of Non-Scaled Environmental Conditions 749
R. Rocchi

HYDROMECHANICS - PROPULSOR AND PROPULSION SYSTEMS, SPECIAL APPLICATIONS

An Investigation into Effective Boss Cap Designs to Eliminate Propeller Hub Vortex Cavitation 757
M. Atlar and G. Patience

LIUTO Development and Optimisation of the Propulsion System; Study, Design and Tests 771
G. Bertolo, A. Brighenti, S. Kaul and R. Schulze

A New Concept of Pushboat Design 785
B. Bilen and M. Žerjal

HYDROMECHANICS – PROPULSOR AND PROPULSION SYSTEMS, MISCELLANEOUS

On the Practical Computation of Propulsion Factors of Ships 793
Do-Sung Kong, Young-Gi Kim and Jae-Moon Lew

Model Test Results of a Twin Screw Vessel with Only One Shaft Line Working 801
Antonio Guerrero

Design Studies of the Manoeuvring Performance of Rudder-Propeller Systems 807
A.F. Molland, S.R. Turnock and J.E.T. Smithwick

SHIP STRUCTURES AND MATERIALS

STRUCTURES - FATIGUE CONSIDERATIONS

The Development of a Fatigue Centred Safety Strategy for Bulk Carriers <i>I.T. Braidwood, I.L. Buxton, P.W. Marshall, D. Clarke and Y.Z. Zhu</i>	819
Single or Double Side Skin for Bulk Carriers? <i>W. Fricke</i>	829
Fatigue of Bulk Carrier Side Frame Structures <i>Anil K. Thayamballi and Zheng-Wei Zhao</i>	839
Fatigue Life Prediction for Ship Structures <i>J.H. Vink, M.Mukhopadhyay and B. Boon</i>	847
Long Term Accumulation of Fatigue Damage in Ship Side Structures <i>Are Johan Berstad and Carl Martin Larsen</i>	855
Fatigue Testing of Large Scale Details of a Large Size Aluminium Surface Effect Ship <i>O.D. Dijkstra, A.W. Vredeveldt, G.T.M. Janssen and O. Ortman</i>	865

STRUCTURES - FATIGUE CONSIDERATIONS, STIFFENED PANELS

Fracture of a Stiffened Panel with Multiple Site Cracks under Lateral Pressure <i>Y. Sumi, Z. Bozic, H. Iyama and Y. Kawamura</i>	873
Fatigue of all Steel Sandwich Panels - Applications on Bulkheads and Decks of a Cruising Ship <i>P. Kujala, K. Kotisalo and T. Kukkanen</i>	879
Enhanced Structural Connection between Longitudinal Stiffener and Transverse Web Frame <i>S.N. Kim, D.D. Lee, W.S. Kim, D.H. Kim, O.H. Kim, M.H. Hyun, U.N. Kim, F.L.M. Violette and H.W. Chung</i>	889

STRUCTURES - FATIGUE CONSIDERATIONS, MISCELLANEOUS

Study on Fatigue Damage Accumulation Process by Using Crystalline FEM Analysis <i>N. Osawa, Y. Tomita and K. Hashimoto</i>	897
Fatigue Damage in the Expansion Joints of SS Rotterdam <i>H.W. Stapel, A.W. Vredeveldt, J.M.J. Journée and W. de Koning</i>	905
A Development of Technical Database for Hull Structures <i>Hirohiko Emi, Toshiyuki Shigemi and Hiroshi Ochi</i>	913

STRUCTURES - NOISE AND VIBRATIONS

Prediction of Propeller Cavitation Noise on Board Ships 919
C.A.F. de Jong and M.J.A.M. de Regt

Computation of Structure-Borne Noise Propagation in Ship Structures using Noise-FEM 927
~~*C. Cabos and J. Jokat*~~

The Acoustic Source Strength of Waterjet Installations 935
K.N.H. Looijmans, R. Parchen and H. Hasenpflug

Viscoelastic Passive Damping Technology on Ship's Vibration and Noise Control 943
Wei-Hui Wang, Rong-Juin Shyu and Jiang-Ren Chang

Dynamic Loads on Fast Ferry Hull Structures Induced by the Engine-Propeller System 951
D. Boote, A. Carcaterra, P.G. Esposito and M. Figari

STRUCTURES - INFLUENCE OF NEW MATERIALS INCLUDING HYBRID SOLUTIONS

Minimum Plate Thickness in High-Speed Craft 959
P. Terndrup Pedersen and Shengming Zhang

X-Joints in Composite Sandwich Panels 967
A.W. Vredevelde and G.T.M. Janssen

An Energy-Based Approach to Determine Critical Defect Sizes in FRP Ship Structures 975
H.J. Phillips and R.A. Shenoi

OFFSHORE ENGINEERING

OFFSHORE - FLOATING PRODUCTION SYSTEMS

Verification of FPSO Structural Integrity <i>R. Potthurst and K. Mitchell</i>	98
--	----

Integrated Motion, Load and Structural Analysis for Offshore Structures <i>Yung Shin, Craig Lee and D.E. Jones</i>	99
---	----

Wave Drift Forces and Responses in Storm Waves <i>C.T. Stansberg, R. Yttervik and F.G. Nielsen</i>	100
---	-----

OFFSHORE - MOORING TECHNOLOGY AND ANCHORLINE DYNAMICS

A Practical Method for Mooring Systems Optimum Design <i>Oscar Brito Augusto, Carlos Alberto Nunes Dias and Ronaldo Rosa Rossi</i>	101
---	-----

A Practical Design and Dynamic Characteristics of a Deep Sea Mooring System <i>H.S. Shin, J.W. Cho and I.K. Park</i>	102
---	-----

Analysis of Dynamic Response of a Moored Tanker and Mooring Lines in a Single Point Mooring System <i>Yojiro Wada and Yoichi Yamaguchi</i>	102
---	-----

OFFSHORE - FLOATING AIRPORTS

Wave Drift Forces of a Very Large Flexible Floating Structure <i>H. Maeda, T. Ikoma and K. Masuda</i>	103
--	-----

Numerical and Experimental Study on Attitude Control of a Large Floating Offshore Structure by Pneumatic Actuator <i>Tsugukiyo Hirayama, Ning Ma and Yasuhiro Saito</i>	104
--	-----

Simulation Study on Oceanophysical Environment around a Large Floating Offshore Structure Moored in Tokyo Bay <i>M. Fujino, K. Seino, M. Hasebe and D. Kitazawa</i>	105
--	-----

OFFSHORE - MISCELLANEOUS

Downtime Minimization by Optimum Design of Offshore Structures <i>G.F. Clauss and L. Birk</i>	106
--	-----

Optimisation of DP Stationkeeping for New Generation Early Production Drillships <i>Albert A. Aalbers and Richard P. Michel</i>	107
--	-----

Mathematical Description of Green Function for Radiation Problem of Floating Structures in Waves <i>Y.Y. Wang, K. Qian and D.Z. Wang</i>	108
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INDEX OF AUTHORS	108
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Enlarged Ship Concept Applied to RORO Cargo/Passenger Vessel

J.M.J. Journée¹, Jakob Pinkster¹ and S.G. Tan²

¹Department of Marine Technology, Delft University of Technology,
Mekelweg 2, 2628 CD Delft, The Netherlands

²Research and Development Department, Marin,
P.O. Box 28, 6700 AA Wageningen, The Netherlands

The "Enlarged Ship Concept" (ESC) was successfully applied to a fast semi-planing 26 m. patrol boat by Keuning and Pinkster [1,2]. Their results showed a significant performance improvement both in a technical and economical sense. In order to investigate if ESC may also render a similarly successful design strategy for a RORO/Passenger vessel which is representative for present services in the UK-West Europe route, the underlying study was carried out. The outcome of this study is that some important results are quite the opposite to those of the patrol boat; this is mainly due to the large difference in vessel types and Froude numbers involved. Within a given payload weight, the larger RORO vessels have more cargo carrying capacity in terms of trailers; in other words, the enlarged vessels can carry more trailers if the trailers are not fully laden. Furthermore, the larger vessels are less vulnerable in damaged condition since the lower hold is not used for cargo and can therefore freely be optimally subdivided. Also advantageous is the fact that the draft decreases as the length increases which results in a higher freeboard for the larger vessels. Summarising, it appears that application of ESC to this type of vessel creates more income possibilities for the shipowners and a much safer vessel, but it produces a more expensive ship to buy and exploit.

1. INTRODUCTION

In 1995 Keuning and Pinkster [1] explored the so-called "Enlarged Ship Concept" (ESC) by applying this to a fast 25 knot, semi-planing, 26 m. patrol boat. The Froude number was, based on vessel length, equal to 0.81. The main driver behind this application was the fact that a monohull sailing at high forward speed in head waves may incur unacceptably high vertical accelerations which may hamper the safe operability of the craft. In essence, they improved the seakeeping behaviour and decreased the resistance of the fast patrol vessel by increasing the length in steps of 25% and 50% and so increased also the length to beam ratio, reduced the running trim under speed and improved the general layout of the ship. Their work carried concerned three design concepts, namely a base boat with two enlarged ship configurations. The key to the ESC is that deadweight, i.e. payload, fuel and stores as well as vessel speed remain constant and equal to that of the base boat. The most important results from this study showed, on the one hand, a 8% marked improvement regarding a decrease in

vertical acceleration in the wheelhouse in head seas and a 40 % decrease in required propulsion power in calm water at a speed of 25 knots; on the other hand the maximum purchasing price of the largest design alternative was estimated to be only 6% higher than that of the basic 26 m. patrol boat.

In 1997 Keuning and Pinkster [2] presented further research on the ESC topic, extensive model testing related to vessel resistance and motions were carried out and subsequent results were described in detail. This second study confirmed the results of the first study and favoured, once again, the Enlarged Ship Concept. In the meantime, the results from these studies have been applied to a number of new buildings of fast patrol boats in The Netherlands. Now, the question arises, " Can the ESC also be successfully applied to the common work horse of the seas, the ordinary marine freighter? "

In the present paper, an attempt was made to answer this question by applying the same ESC to a full time "freight carrying" vessel being a RORO/Passenger Vessel representative for present services in the UK-West Europe route. The base vessel of 157 m. length

was lengthened by respectively 25 and 50 per cent, while deadweight and speed remained constant. The consequences with regard to vessel mass, stability and trim, cargo hold configuration, propulsion power, freeboard, net tonnage and building costs were evaluated. On the operability side, seakeeping performance as well as operability were also assessed. Finally costs were determined for the base ship as well as for the two ESC alternatives.

2. THE "BASE SHIP"

The base vessel used for the study was m.v. NORBANK owned by North Sea Ferries and built in 1993 by the Dutch shipyard Van der Giessen-de Noord. This vessel is a well proven design and has been described in more detail in [3]. The vessels main particulars are given in table 1. All design and functional requirements, such as speed, payload, accommodations etc., for the Enlarged Ship Concepts were based on and kept identical to those of this base ship. Relevant design information regarding hull form, stability and trim, masses, building costs etc. of the basic monohull were kindly made especially available to the authors for the work carried out here.

3. THE "ENLARGED SHIP" DESIGNS

To yield the Enlarged Ship Concepts the basic 157.65 m. ship, forthwith designated ESC-0, was enlarged in length only. Two such designs alternatives, ESC-1 and ESC-2, were made, having a length of respectively 197.06 m. and 235.85 m. . The enlarged alternatives are shown in Figure 1 along with the base ship whereas the main design particulars for all designs are given in Table 1.

With regard to engineering of all these alternatives the starting point was relative data related to the base ship. The increase in length was, in both cases, created by inserting a parallel midship section with respective lengths of 25% Lpp and 50% Lpp. In this way the original body plan remained unchanged in both the forward and aft part of all design alternatives; thus keeping the good lines of flow to the propellers and along the bow. Subsequently hydrostatic particulars were computed for the new body plans.

The increase in structural masses of all alternatives was also computed via the original mass data which

was augmented with extra frames and hull plating, taking into account the relevant positions of the centres of gravity of all components of the designs. Also, since an increase in vertical bending moment may be expected to be approximately proportional to the square of the length ratio for the enlarged vessels, i.e. 1.55 and 2.25, an extra allowance has been made for an increase in steel mass of the parallel midship sections of respectively 20% and 45% for the ESC-1 and ESC-2 alternatives. This extra steel, in the form of deckplating, is thought to be placed in the upper deck of the midship section as it is then effectively positioned furthest from the neutral line and thereby reduce the bending stresses to an equal level of the base ship. The deadweight of the enlarged vessels was placed in such a manner that no trim angles occurred.

The resistance and propulsion calculations were also made for each alternative.

Since the idea behind the Enlarged Ship Concept is equal payload for all possible alternatives, similar main dimensions such as breadth, depth etc., the vessel configuration (i.e. also position of accommodations, wheelhouse etc. with respect to the bow) remains unchanged to that of the basic ship for each design alternative concerned. Consequently, the forward position of the wheelhouse has a distinctive disadvantage with regard to ship motions.

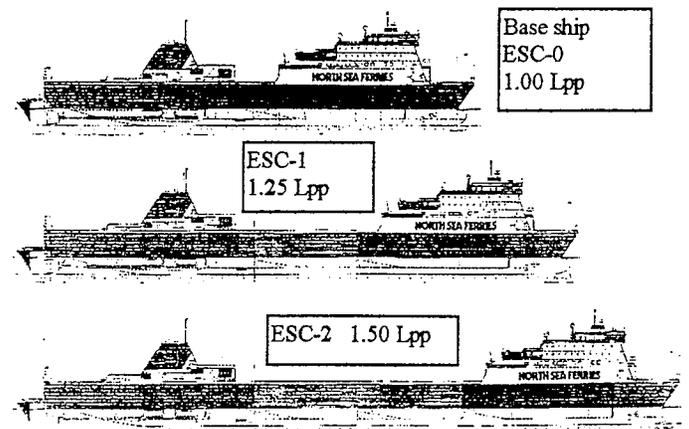


Figure 1. Side elevation of base ship and ESC designs.

4. SHIP RESISTANCE

The still water resistance for all three designs was calculated using the method of Holtrop and Mennen [4] for a range of speeds up to the design speed of 22 knots. This speed corresponds to a Froude number of

0.29 for the base ship. Figure 2-a shows the still water resistance coefficients (C_T) of the three ships, subdivided into frictional (C_f) and residual (C_r) parts. From this figure it appears that, when comparing with the base ship ESC-0 at a speed of 22 knots, ESC-1 has a decrease in resistance coefficient of about 15 per cent while ESC-2 shows 10 per cent decrease only. However, this favourable effect becomes completely lost due to an increase of the wetted surface of the hull with 20 and 45 per cent respectively. As a result of this the total still water resistance will increase with approximately 5 and 30 per cent for ESC-1 and ESC-2, respectively; see Figure 2-b.

An important conclusion regarding still water resistance is that, when the Enlarged Ship Concept is applied to these ships, there is not a similar profit to be gained as for the fast semi-planing patrol boats from [1] with up to 40%

reduction in still water resistance. This finding may be attributed to the relative low Froude numbers (0.29 for ESC-0) compared to those of the patrol boats (0.81 for the base ship).

Since the vessel resistance is known for m.v. NORBANK (ESC-0), a ratio between actual and computed resistance was determined. This correction coefficient was then applied to the computed resistance of the larger vessels for establishing the required propulsive power.

Since the topic investigated in this paper deals with large seagoing vessels, ship motions are calculated at 20 and 15 knots. When assuming that the still water resistance is proportional to at least the square of the ship speed and using calculated data on added resistance in seaway, a sustained sea speed in rough weather dropped from 22 to 15 knots would expect to be an acceptable average.

Table 1
Main particulars of the base ship and alternative ESC designs

Parameter	Dim.	ESC-0	ESC-1	ESC-2
Loa	m	166.77	206.18	244.97
Lpp	m	157.65	197.06	235.85
Bmld	m	23.40	23.40	23.40
T	m	5.80	4.97	4.50
KB	m	3.26	2.69	2.36
BM	m	9.01	10.25	11.35
KG	m	10.42	10.83	10.87
MG	m	1.85	2.11	2.84
Cb	[-]	0.61	0.64	0.66
Depth to main deck	m	8.60	8.60	8.60
Depth to upperdeck	m	14.40	14.40	14.40
Lightshipweight	t	7417	9126	11176
Deadweight	t	6020	6020	6020
Displacement	t	13437	15146	17196
Speed	kn	22	22	22
Propulsion power	kW	24480	25700	33500
Passengers	no	120	120	120
Lane length upperdeck	m	930	1190	1450
Lane length maindeck	m	910	1170	1430
Lane length hold	m	200	0	0
Trailer capacity @ 40 t	no	156	165	165
Water ballast	t	234	0	0
Gross tonnage	GT	17464	21452	25396
Net tonnage	NT	5239	6436	7619
k_{xx}/B	[-]	0.43	0.43	0.43
k_{yy}/L_{pp}	[-]	0.29	0.29	0.29
k_{zz}/L_{pp}	[-]	0.29	0.29	0.29

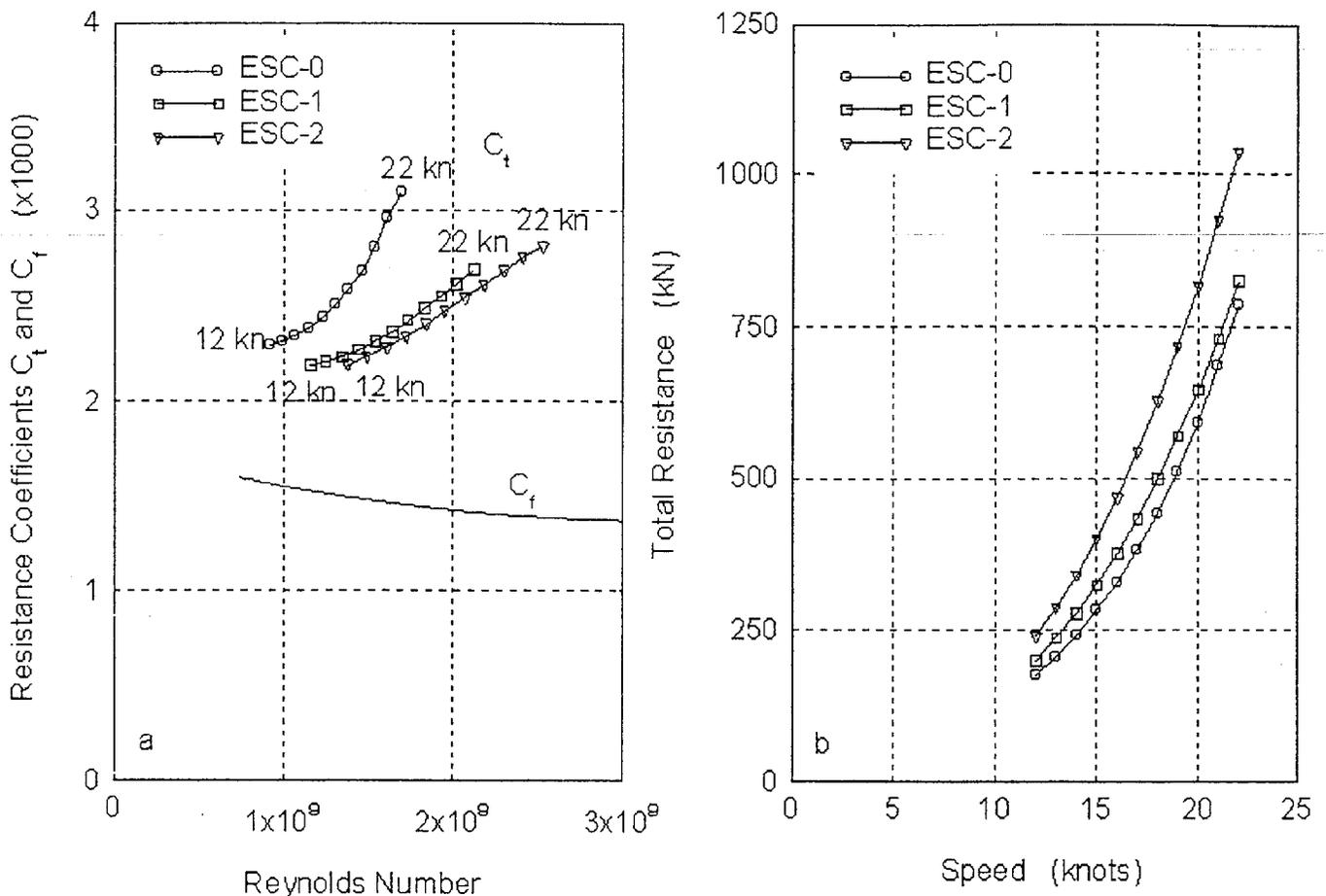


Figure 2. Results of resistance calculations.

5. SHIP MOTIONS

The vessel motions were calculated using the linear strip theory program SEAWAY of the Delft Ship Hydromechanics Laboratory [5]. These calculations were carried out in Beaufort 7 to 12, at wave directions ranging from head to following seas. The energy distribution of the irregular waves in the considered coastal areas was described by unidirectional JONSWAP wave spectra. According to Hasselmann [6], this wave energy distribution is a favourable choice for a fetch limited seaway. A commonly used relationship between period, wave height and Beaufort number was utilised. The long term probability on exceeding a certain sea state was obtained from Global Wave Statistics whereas the limiting criteria of ship motions were obtained from Karppinen [7].

In order to assess the ship's radii of gyration, an analysis has been made of the mass distribution over the length of the various designs.

Figure 3-a shows the vertical significant acceleration

amplitude at the bridge in head seas as a function of the Beaufort scale with an acceleration criterion of 0.3 g. At both speeds course can be maintained by ESC-0 in sea states up to Beaufort 8, which will be exceeded during about 2 percent of the year.

However not unexpected, the two enlarged ships ESC-1 and ESC-2 can maintain their course up to Beaufort 9 and 10 respectively. Figure 3-b shows the probability on slamming in head waves, defined by a relative vertical velocity criterion at the bow. Using a slamming criterion of 2 per cent, all ships can maintain their course up to Beaufort 8. The effect of ship size and forward speed on slamming appears to be relatively small.

Figure 3-c shows the horizontal significant acceleration amplitude at the bridge in beam seas as a function of the Beaufort scale with an acceleration criterion of 0.24 g. The effect of forward ship speed is negligible. Course can be maintained by ESC-0 and ESC-1 in sea states up to Beaufort 9, which will be exceeded during less than 1 percent of the year. However, the operability of ESC-2 is limited to

Beaufort 8, which sea state will be exceeded during about 2 per cent of the year.

Figure 3-d shows the significant roll amplitude in beam seas as a function of the Beaufort scale with a roll criterion of 12 degrees. The effect of forward ship speed is negligible. The ships heading can be maintained by ESC-0 and ESC-1 in sea states up to above Beaufort 11, but the operability of ESC-2 is limited to Beaufort 10. However, the probability of occurrence of this sea state is only 0.2 per cent.

From these calculations it was concluded that the overall motional behaviour of ESC-1 is comparable with that of ESC-0. The behaviour of ESC-2 is somewhat better in head seas and somewhat worse in beam seas when compared to the base ship.

The largest impact of all may be found when evaluating bending moments.

Figure 4-a shows the distribution of the vertical bending moment (M_y) in still water over the ship length. Compared to ESC-0, for the enlarged vessels these moments have been increased by approximately 40 and 60 per cent. According to the classical theory of a uniformly loaded elastic beam, simply supported at both ends, the vertical bending moment increases with the square of the length of the beam. When considering a vessel positioned in a longitudinal (quasi static) wave with a length equal to that of the ship and the wave crests at both ends, one can expect a similar increase in vertical bending moments for the enlarged ships (55 and 125 per cent respectively). This simple approach to the problem is confirmed by dynamic calculations of the vertical bending moment (M_y) in head seas (rendering increases of about 50 and 150 per cent respectively); see Figure 4-c.

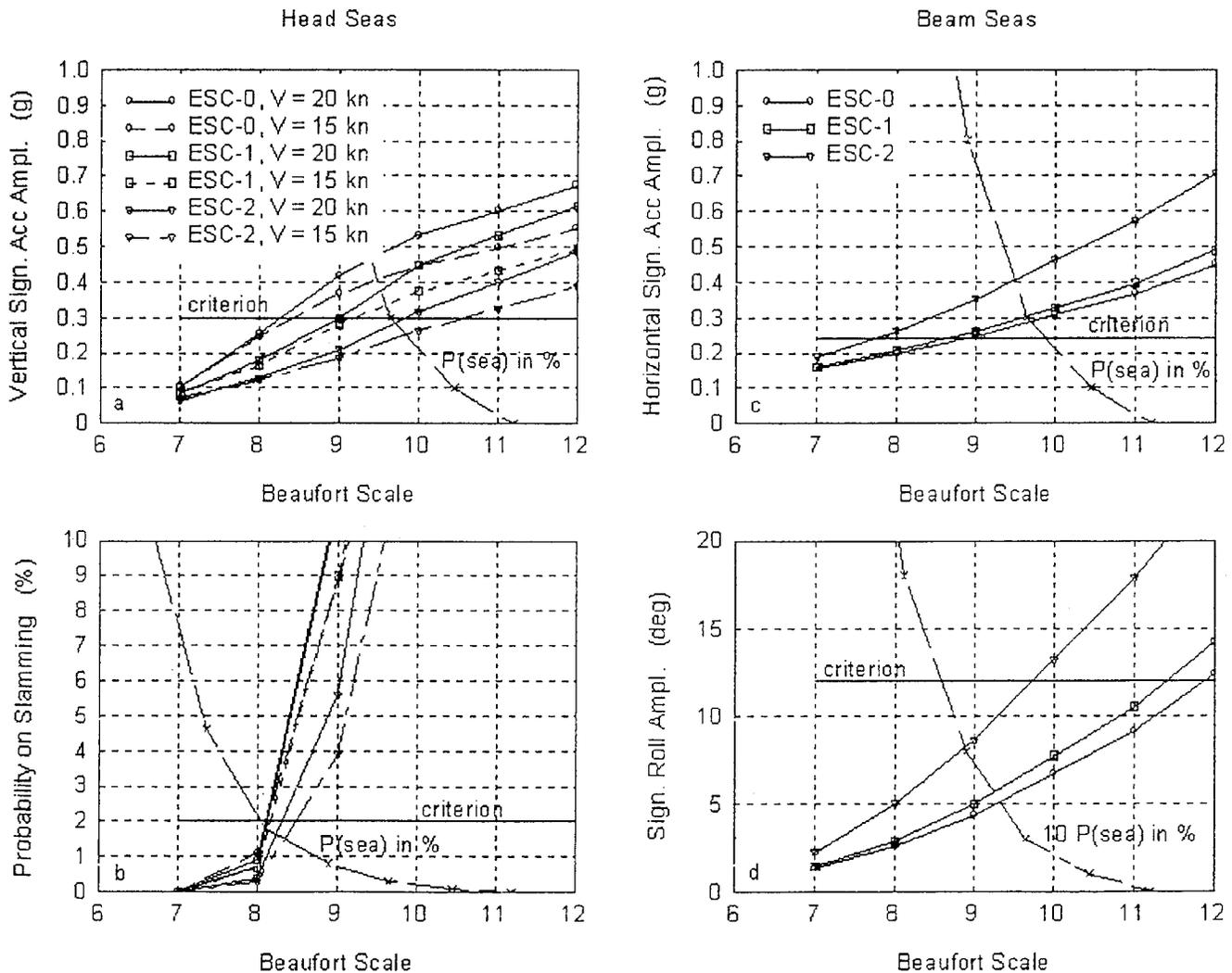


Figure 3. Motional behaviour of ESC's in seaway.

The largest horizontal bending moments (M_z) and torsional moments (M_x) have been found in bow-quartering waves ($\mu=120^\circ$); see figures 4-b and 4-d for the corresponding significant amplitudes. The stresses caused by the torsional moments (M_x) do not play an important role because of the closed character of the midship section. As the lateral bending moments (M_z) are much smaller than the vertical bending moments (M_y) the latter is dominant for this shiptype. Considering similar main frame scantlings for all three designs, the result would be an increase in bending stresses in the outer fibres of the larger vessels in the order of 55 and 125 per cent respectively. To deal with this increase, an increase in scantling mass for the enlarged part of the vessels

has been allowed for about 20 and 45 per cent respectively. Since this extra mass is mainly required in the midship section, the mass distribution is assumed to have the form of a triangle with its base length equal to the length of the enlarged part and its top in the middle of it. This extra mass is distributed as such, in the upper deck of the vessels, having thereby the most optimum effect in reducing bending stresses. As the ends of the enlarged part are the original midship section, here lower scantling dimensions can now be expected due to a distance from amidships. However, this will be, more or less completely, overruled by the effect of an increase of the ship length.

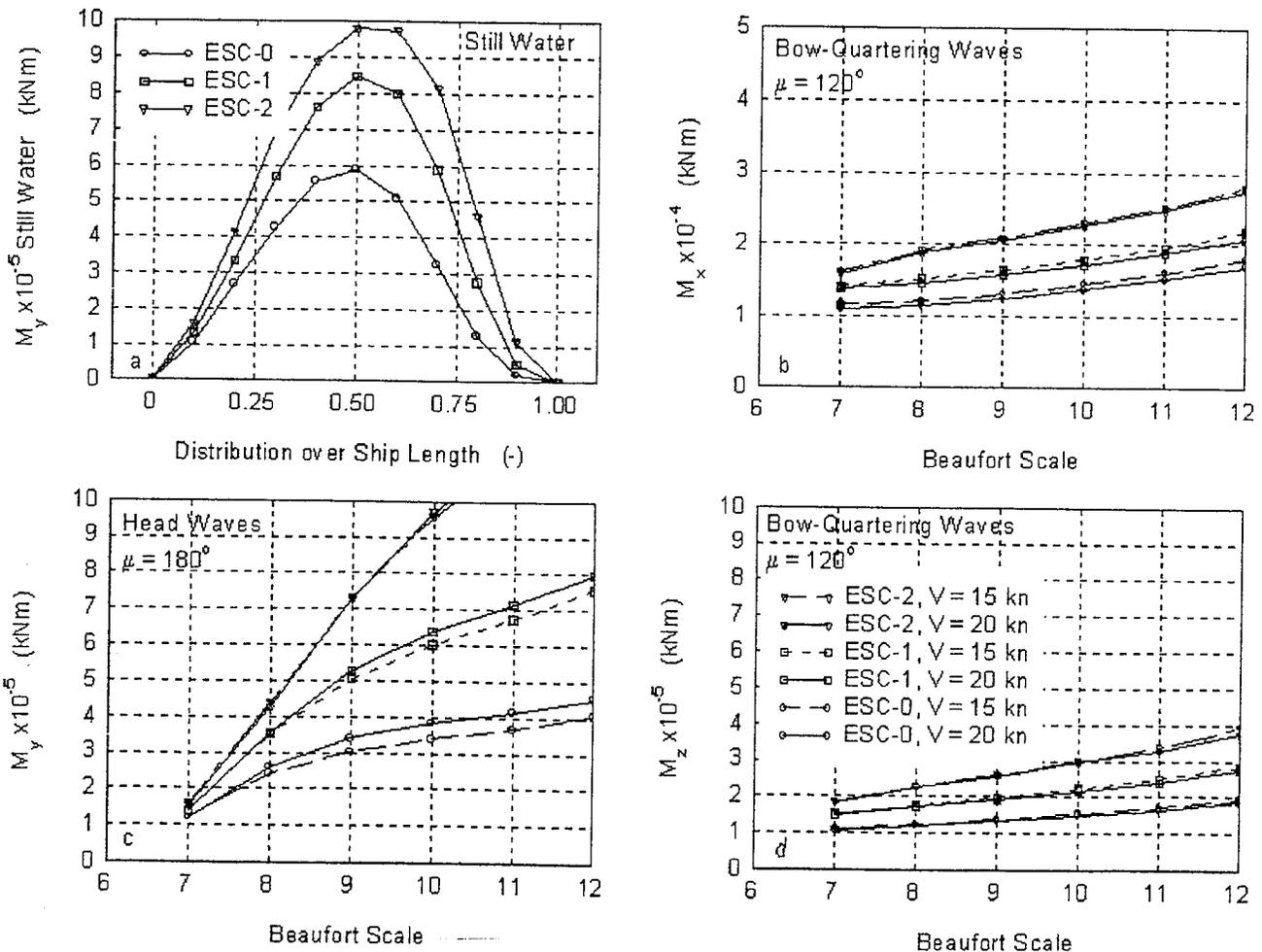


Figure 4. Torsional, vertical and horizontal moments.

6. ECONOMIC EVALUATION

In order to make an economical evaluation the building costs of the different design alternatives were estimated using the original building costs of

the base ship (of which all costs components were known) and correcting this for changes in steel mass of the hull and extra painting costs (i.e. cleaning, preparation and painting) and also for extra machinery costs. The differences in building costs

are indexed with regard to the ESC-0 in Table 2. Note the increase in building costs of about 10% for ESC-1 and 28% for ESC-2.

The operational costs of the design alternatives are considered for a scenario of a twenty year economic life of the ship, sailing 18 hours per day at 22 knots, 7 days a week for 48 weeks per year and crewed by 30 persons (3 shifts per 24 hours). The differences in operational costs are indexed with regard to the ESC-0 in Table 2. Note the relatively high increase in operational costs of about 8% for design alternative ESC-1. This increase is even more dramatic in the case of the ESC-2 design alternative (i.e. 18%).

The transport efficiency (TE) - defined, in this particular case as: number of trailers times service speed in m/s over installed power in kW - has been calculated for the three designs. The differences in TE are indexed with regard to ESC-0 in Table 2. When dealing with trailers of 40 ton: an increase in TE of only 1% for ESC-1 is gained, while a decrease of about 20% is calculated for ESC-2. However, when allowing less than 40 ton per trailer and utilising the available trailer space on both D and E decks, the increase of TE becomes 17 and 13 per cent respectively.

Applying the enlarged ship concept to such a RORO vessel as presented in this paper, renders an improvement in concept design with regard to the increase in the transport capacity of non fully laden trailers; the stipulated condition that payload remains constant must still be applied. When allowing fully laden 40 tons trailers of 12.2 m length, the number of trailers transported by the design alternatives are approximately 6% higher than that of the base ship. This is due to the fact that the larger vessels do not require 234 ton of ballast in the fully loaded condition.

Furthermore, when keeping payload constant, the larger design alternatives have relatively enough space available on both D and E decks for the carriage of homogeneous cargo of respectively 191 trailers of 34.6 ton and 233 trailers of 28.3 ton. This is an increase by respectively 22% and 49% compared to the base ship. Based on a single price per trailer, the earning capacity of the larger alternatives will therefore increase with a similar percentage if, and when, the market has lighter trailers on offer.

If only the D and E decks are utilised for the carriage of trailers, loading and discharging times per trailer will be relatively reduced due to the fact that these

decks are more easily accessible than the lower F hold.

Table 2
Results of economical calculations

Index	ESC-0	ESC-1	ESC-2
Building costs	1.00	1.10	1.28
Power at 22 knots	1.00	1.05	1.32
Operational costs	1.00	1.08	1.18
Transport efficiency ¹	1.00	1.01	0.80
Transport efficiency ²	1.00	1.17	1.13
Trailer capacity ¹	1.00	1.06	1.06
Trailer capacity ²	1.00	1.22	1.49

¹ 12.2 m. trailers total all in load of 40 tons each

² idem with all in load of less than 40 tons each

Although not advocated by the authors, if (the lowest) F deck were included within the cargo carrying capacity, space would be available for yet another 28 and 40 trailers for the alternatives. This would result in the carriage of homogeneous cargo of respectively 219 trailers of 30.1 ton 273 trailers 24.2 ton. This is an increase of 40% and 75% respectively, compared to the base ship. The earning capacity of the alternatives will therefore increase with a similar percentage if, and when, the market has lighter trailers on offer and the price per trailer is independent of the mass carried within.

7. CONCLUSIONS

The following conclusions are drawn with regard to the feasibility of the Enlarged Ship Concept applied to a freight carrying vessel (see also table 2):

- The ESC when applied to such large and relatively moderate Froude number vessels appears, at first glance, to be far less viable than for the fast patrol boat. This is mainly due to the relatively larger increase in building and exploitation costs.
- Heave, pitch and related phenomena on the bridge of such a RORO vessel in waves, although not excessive, are sufficiently reduced by the application of ESC.
- Roll motions on the bridge of such a RORO

vessel in waves are increased by the application of ESC. However this increase is still acceptable with the criteria applied.

- The vertical midship bending moment in rough weather increases largely for the larger design alternatives; in Beaufort 10 the increase is of the same order as the expected increase of the calm water bending moment which is proportional to the square of the ratio between vessel length and base ship length.
- In the case of the RORO Freighter/Passenger cargo vessels, a definitive advantage of the ESC is the provision of space for the accommodation of lighter cargoes if available which consequently increase the earning capacity and transport efficiency.
- Applying ESC to a RORO vessel renders an improvement in concept design with regard to a significant improvement in survival capability after having suffered the ingress of water into the hull; the condition that the lowest hold remains empty and optimally subdivided for this purpose must be respected.

8. RECOMMENDATIONS

Further optimisation of the enlarged designs of the RORO freighter/passenger ferry may well lead to more promising results and is recommended as follows:

- Optimise the vertical position of the upper deck of the enlarged vessels in order to reduce the vessel mass, while, at the same time, satisfying the requirements regarding allowable stress values due to longitudinal bending moments.
- Optimise the mass of the enlarged vessels by the utilisation of high tensile steel. This will surely reduce the vessel mass while at the same time being able to withstand the higher longitudinal bending stresses.
- Optimise the vessel form with regard to vessel resistance and propulsion. This can be done by optimisation of the longitudinal centre of

buoyancy, ships lines, etc.

- Optimise the vessels turn around time by not utilising the F deck for the carriage of trailers.

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